It seems probable that both classes of effects are involved in the actual magnetisation in question, though experiment has shown that any effect of class (*a*) is at least exceedingly minute unless the magnetic behaviour of the interior parts of the earth and sun is quite different from that of matter at ordinary temperatures on the surface of the earth.

S. J. Barnett.

The Ohio State University, Columbus,
Ohio, U.S.A., March 12.

A Triangle that gives the Area and Circumference of any Circle, and the Diameter of a Circle equal in Area to any given Square.

It is not possible to measure *exactly* the interminable fraction required for the line BZ in the following figure, but it is quite easy to draw it so nearly that the error is practically immensurable.

First Method.—Draw a line AB = 44, and make BZ = 23. $\frac{23}{44} = 0{\cdot}52272\dot{7}\dot{2}$, which is a little too long.

AY will then be short, about 1 in 600,000.

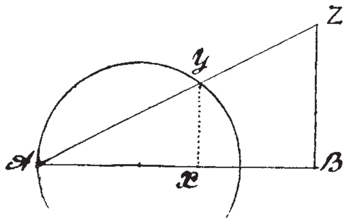
AX will also be short, about 1 in 300,000.

Second Method (with the familiar ratio $\frac{355}{113}$). Make a circle with diameter AB = 11·3, and let AX = $8\frac{7}{8}$. Draw a perpendicular from X to cut the circle in Y. Join AY, and continue the line to Z.

Then the error in AX, the $\frac{1}{4}$ circumference, will be less than 1 in 11,780,000 *in excess*.

The true angle for the line AZ lies between the lines found by the two methods, but the difference is too small for measurement, and in any accurate drawing the lines will appear to coincide.

AX being found, equal to an arc of 90°, a line for any other arc may be found; and the triangle once drawn on a sufficiently large scale, is true for all circles.



$$\left.\begin{array}{l}\text{Let AB} = 1\text{, and at right angles}\\ \text{BZ} = 0{\cdot}5227232008+\text{, join AZ}\end{array}\right\}\ \text{Angle A. } 27^\circ\ 35'\ 49{\cdot}6''+$$

Then, any circle with diameter upon AB and one extremity at A, will cut the line AZ (or AZ produced) in a point Y, making AY the side of a square equal in area to the circle.

Also, a line from Y perpendicular to AB will cut the diameter in a point X, making AX equal to $\frac{1}{4}$ circumference of the circle.

Again, any square with base upon AB and a corner at A, will, with its side opposite to A, cut AZ in a point Y, making AY the diameter of an equal circle.

T. M. P. Hughes.

5 The Croft, Tenby.

The following remarks may help to explain Mr. Hughes's constructions:—

Let AY be a chord of a circle of which AD is a diameter, and let $\angle \text{DAY} = \theta$. Then if the square on AY equals the area of the circle, $(2r\cos\theta)^2 = \pi r^2$, and therefore $\cos^2\theta = \pi/4$, $\tan^2\theta = (4-\pi)/\pi$, and

$$\tan\theta = 0{\cdot}5227232,$$

very nearly, as stated. Now if we express this approximate value of $\tan\theta$ as an ordinary continued fraction we find the successive convergents,

$$1/1,\ 1/2,\ 11/21,\ 12/23,\ 23/44,\ \text{etc.},$$

where the first of those not written has four digits in numerator and denominator. Hence, as Mr. Hughes has discovered, 23/44 is a very close approximation to the transcendent number $\sqrt{(4-\pi)}/\sqrt{\pi}$. It seems absurd to speak of a mathematical accident, but we do seem to have something of the kind here. Supposing that a/b is a rational approximation to $\sqrt{(4-\pi)}/\sqrt{\pi}$, we should not expect beforehand a solution correct within about $4{\cdot}10^{-6}$ for values of *a, b*, each less than 100.

The second construction is obtained by putting, as an approximation,

$$\text{AX} : \text{AD} = \pi/4 = 355/4{\cdot}113 = 710/8{\cdot}113 = 8\tfrac{7}{8}/11{\cdot}3.$$

It would be easy to make a set-square with its shorter sides in the ratio 23 : 44, and this could be used for the approximate quadrature and rectification of any given circle. It is interesting to see how the same figure solves both problems to the same degree of exactness (practically). I suppose the error in the set-square could be reduced to 0·1 per cent., or less; the question is, what percentage of error is likely to occur in using it. For the rectification we have to draw the perpendicular YX; it seems to me that for the quadrature we are likely to obtain the most accurate results by using a straight edge as well as the set-square; that is to say, we should not try to adjust the set-square without first placing a straight edge along a diameter of the circle. If this is so, the graphical solutions of both problems are likely to be affected by the same percentage of error; because to obtain X, after marking Y, we have only to slide the set-square along the straight edge until a shorter side goes through Y; and if we repeat the manipulation several times, I do not think the error in finding X, regarded as a distance from the true position, can be so much as five times the error in finding Y, or conversely. Of course, by "the same percentage of error" I mean here that the two errors, on the same scale, are of the orders $\pm a{\cdot}10^{-n}$, $\pm b{\cdot}10^{-n}$, where *a, b* both lie above 1, while neither of them is equal to, or exceeds, 5.

G. B. Mathews.

New Units in Aerology.

With reference to Prof. McAdie's letter in Nature of March 19, p. 58, I should like to point out that throughout my "Thermodynamics," published in 1878, a megadyne per square centimetre is used as the unit of pressure, and it is termed a c.g.s. atmosphere. Ever since 1888, when the B.A. committee (of which I was a member), adopted the barad, I have employed in my lectures the above pressure unit under the name of megabarad. The corresponding unit of work, and also of heat, adopted in the book is the megalerg. Megerg to my ear is too cacophonous for use.

Robert E. Baynes.

Christ Church, Oxford, March 25.

PROGRESS IN WIRELESS TELEPHONY.

The attention of telephonic engineers has of late years been very closely directed to the improvement of the line wire in ordinary telephony. Apart from the imperfections of the telephone transmitter and receiver, *per se*, a very considerable effect is produced on the transmitted speech by the line itself if it is at all long. This action, from an electrical point of view, consists in the distortion of the wave form of the current as it travels along the cable, and its rapid attenuation or diminution in amplitude.

When speech is uttered to the mouthpiece of the transmitter, the current flowing into the line is modulated in a complicated manner, but this variation in virtue of Fourier's theorem can be analysed into the sum of a number of currents of simple harmonic or sine wave form placed in certain relative phases and having certain amplitudes. The velocity W, with which any simple harmonic current travels along a cable having a resistance R ohms, an inductance of L henrys, a capacity of C farads, and a dielectric leakance of S mhos per unit of length, provided that the quantities R/pL and S/pC are small compared with unity, can easily be shown to be expressed by the formula:—

$$W = \frac{1}{\sqrt{CL}} \cdot \frac{1}{\sqrt{1+\frac{1}{p^2}\left(\frac{R}{2L}-\frac{S}{2C}\right)^2}},$$

where $p = 2\pi$ times the frequency.

Accordingly, the greater the frequency, the greater will be the wave velocity. In other words, short waves travel faster than long. The short waves, having also the least energy, attenuate most rapidly.

The result of this is that in the case of telephony along wires the different harmonic constituents of the current get out of step, and degrade unequally. Hence the wave form, and the quality of the received sound, is altered after the wave has travelled a certain distance along the wire or cable. The result is to diminish the loudness and reduce the clearness of the speech heard. Therefore, beyond a certain distance the articulate sound becomes unintelligible.

On the other hand, it is well known that the velocity of electromagnetic waves through space is independent of the wave length, and there is, therefore, in this respect a marked difference between the transmission of electromagnetic waves guided along wires, and free electromagnetic waves diverging through space. As soon as the telephonic or aural method of receiving Morse signals in wireless telegraphy was substituted for the method of employing some form of coherer as a relay to actuate a Morse inker printing them in *dot* and *dash* on paper tape, the suggestion was made that it might be possible to transmit articulate speech by space electromagnetic waves, and not merely Morse signals composed of long and short sounds; and hence to conduct a wireless or lineless telephony.

It was at once recognised that before this could be done it would be necessary to provide a generator of electromagnetic waves giving truly continuous waves, and not merely intermittent groups or trains of rapidly decadent waves. The discovery of the power of the continuous current arc between carbon electrodes to create high-frequency oscillations in a condenser circuit connected between the carbons, held out hopes of making such a generator. It was not, however, until Poulsen discovered the peculiar properties of an electric arc formed in hydrogen or coal gas to enable very high-frequency oscillations to be so generated that progress began to be made. The Poulsen arc-generator consists, as is well known, of a direct-current arc formed with an electromotive force of about 500 volts between a carbon and a copper electrode in an atmosphere of hydrogen or coal gas. A strong transverse magnetic field is also applied to the arc. An inductive circuit, consisting of a coil of wire having in series with it a capacity, the capacity and inductance being so adjusted that the natural frequency of this oscillation circuit is not less than about 50,000, or preferably much higher, even up to 250,000, is then connected between the carbon and copper electrodes. Powerful continuous electric oscillations are then set up in this condenser circuit. These oscillations can be made to set up similar oscillations in an open radiative circuit or antenna, which is inductively connected with the condenser circuit, as in the case of an ordinary wireless telegraph transmitter.

In this manner continuous or uninterrupted electric waves of a wave length which is anything between 1 and 4 or 5 miles, can be radiated from the aerial wire. The reason the hydrogen or coal gas is effective in enabling the arc to create more powerful high-frequency oscillations is that it increases the steepness of the characteristic or volt-ampere curve of the arc, and hence increases the energy which is conveyed to the condenser at each oscillation.

To transmit speech we have then to modify the amplitude of these radiated continuous electric waves sent out from the sending station antenna in accordance with the wave form of the speaking voice. This is done usually by some form of carbon microphone inserted in the base of the sending station antenna. When the diaphragm of the microphone is acted upon by the voice, the carbon granules in it are more or less compressed, and the electrical resistance thereby altered. If then the high-frequency current in the antenna is made to pass through this microphone, the amplitude of the radiated continuous waves will be varied by making speech to the microphone, in such a way as to create waves upon waves, or to alter the wave amplitude in accordance with the wave form of the speaking voice.

At the receiving end all the arrangements are identical with those required in wireless telegraphy when using a telephone and rectifier of some kind to receive audible Morse signals. The receiving antenna is coupled to a closed condenser circuit, and to the terminals of this condenser is attached a Bell receiving telephone in circuit with some oscillation rectifier, such as a crystal or constant detector, viz., carborundum, perikon, or zincite-chalcopyrite, or an ionised gas rectifier such as a Fleming glow-lamp valve. The telephone is then not affected by the rectified continuous oscillations *per se*, but it is affected by the variations in their amplitude produced by the microphone in the transmitter circuits.

Audible and intelligible speech can thus be reproduced at the receiving end. The limitations that present themselves in this transmission are wholly connected with the creation and modulation of the electric waves emitted by the sending station, and chiefly due to the difficulty of designing a microphone which can carry a sufficiently large current without heating. An additional trouble is that of devising a generator which shall be as simple and easily managed as that of a wireless telegraph plant.

As regards the microphone, most workers have employed a number of carbon microphones joined in parallel so as to enable a high-frequency antenna current of, say, 4 or 5 amperes to be passed through them without overheating any one. It is not easy, however, to divide the current equally between the microphones, or to keep them absolutely in step with each other. Another type is the liquid microphone of Majorana, and of Vanni. In Dr. Vanni's microphone a jet of water rendered slightly conducting by acid or salts is allowed to fall on a fixed inclined metal plate, B, and then bounces off on to another inclined metal plate, A, which is in mechanical or electrical connection with the diaphragm of a speaking mouthpiece (see Figs. 1 and 2). Speech, therefore, made to it sets the last-named plate vibrating, and thus breaks up and varies the resistance of the film or column of liquid connecting the two plates. Hence, if this liquid column is in the circuit of the transmitting antenna, any speech made to the diaphragm will vary the electrical resistance in the antenna circuit, and change in a similar manner the amplitude of the radiated electric waves.

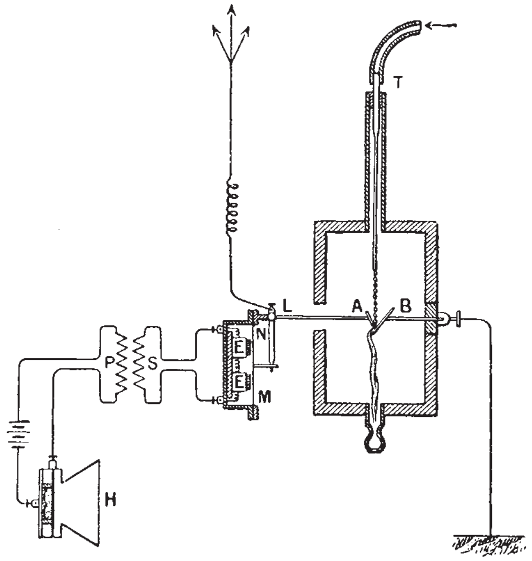


Fig. 1.—The liquid microphone of Dr. J. Vanni.

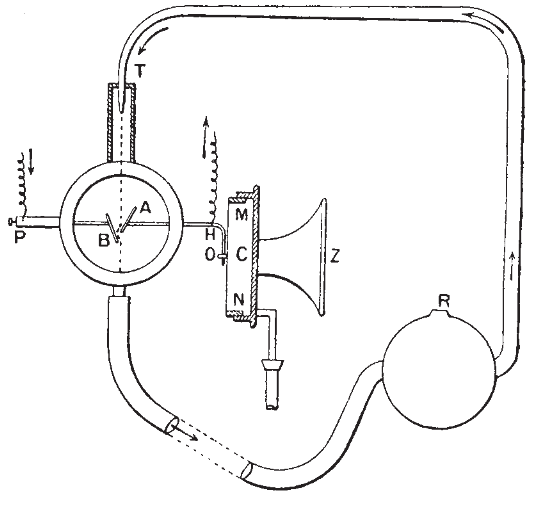


Fig. 2.—Arrangements for circulating the liquid by a rotary pump R in Vanni's microphone.

W. Dubilier has also invented a water-cooled carbon granule microphone, the main diaphragm being moved by the current through a relay microphone to which the speech is actually made. This microphone can pass 700 watts with clear articulation (see Fig. 3). Then with regard to generators, a good many modifications of the arc generator have been produced. The Moretti arc consists of a copper tube kept supplied with water, and another copper rod is brought down so as to strike the arc against the water. When the arc is formed with a continuous current, and is also shunted as above described with a condenser inductive circuit, high-frequency oscillations are set up in the latter. There is a very rapid extinction and re-ignition of the arc, possibly due to some action like that in the Wehnelt interrupter. The writer of this article has also devised recently a new form of arc generator which requires no transverse magnetic field, nor supply of hydrogen or coal gas, as in the Poulsen apparatus. We have, then, in addition, the high-frequency alternator method of creating the oscillations. Fessenden experimented at one time very largely with such machines, devising a form of Mordey alternator which could give a frequency of 80,000 or 100,000. The invention by R. Goldschmidt of a means of multiplying frequency by means of a rotating field alternator made a new departure. By this machine high-frequency continuous oscillations are mechanically created, and their amplitude can be controlled by a microphone placed in the exciting circuit of the machine, so that it is not traversed by the main current.

Furthermore, we have the high speed, smooth disc generator of Mr. Marconi as a means of creating undamped oscillations, and, in addition, a telephonic transmitter has been invented by him which has not yet been described in detail, but was mentioned by him in a recent lecture in Rome. It is known that he has recently directed his attention closely to invention in connection with wireless telephony.

It is also possible to employ spark discharges of a very high spark-frequency, above the limit of audition, as a means of creating what are practically unintermittent oscillations, the separate trains of oscillations being practically in contact with each other. This method depends upon the self-extinguishing power of electric arcs produced between certain metals which are good conductors, such as aluminium and copper. If a pile of plates of these metals with very small air-gaps is built up, and a high electromotive force applied to it, discharges will take place, or small arcs which, when the discharger is shunted by a condenser, can generate high-frequency oscillations. By the aid of these appliances, their inventors and other workers have conducted wireless telephony up to a distance of 1000 kilometres, or, say, five hundred or six hundred miles.

Thus, Dr. J. Vanni, working at Rome, and using a Moretti arc generator, his own liquid microphone, and a form of Fleming oscillation valve as a receiver, has transmitted and received articulate speech between Rome and the Island of Ponza (120 km.), to Maddalena (260 km.), to Palermo (420 km.), to Vittoria (600 km.), and finally between Rome and Tripoli, a distance of 1000 km.

The speech is said to have been clear and singularly free from evidence of distortion of wave form. In addition to this, successful experiments in wireless telephony are said to have been conducted between Berlin and Vienna, a distance of 375 miles, by the Telefunken Company. The stations were the German high-power station at Nauen, to the west of Potsdam, and a receiving station on the roof of the Technological and Industrial Museum at Vienna. The experiments were so promising that it is expected much greater distances can be covered. A very inviting field of work seems to be opening out in connection with the alternator method of generation. With a suitably designed Goldschmidt high-frequency alternation it is said that a small variation in the exciting current will produce very large variations in the amplitude of the radiated waves. Hence the microphone can be placed in the excitation circuit, and need only have a current-passing capacity of a few amperes to be able to modulate a radiation representing a very large horse-power. To transmit articulate speech across the Atlantic will necessitate the power of varying the amplitude of continuous wave radiation representing at least 50 or 100 horse-power. This must be done by means of some microphone which passes not more than, say, 10 amperes. These conditions are not impossible of attainment. Hence Transatlantic wireless telephony may be said to be within the range of practical politics, whilst no improvements yet made in submarine telephonic cables hold out hope of being able within any reasonable time to speak through an Atlantic cable.

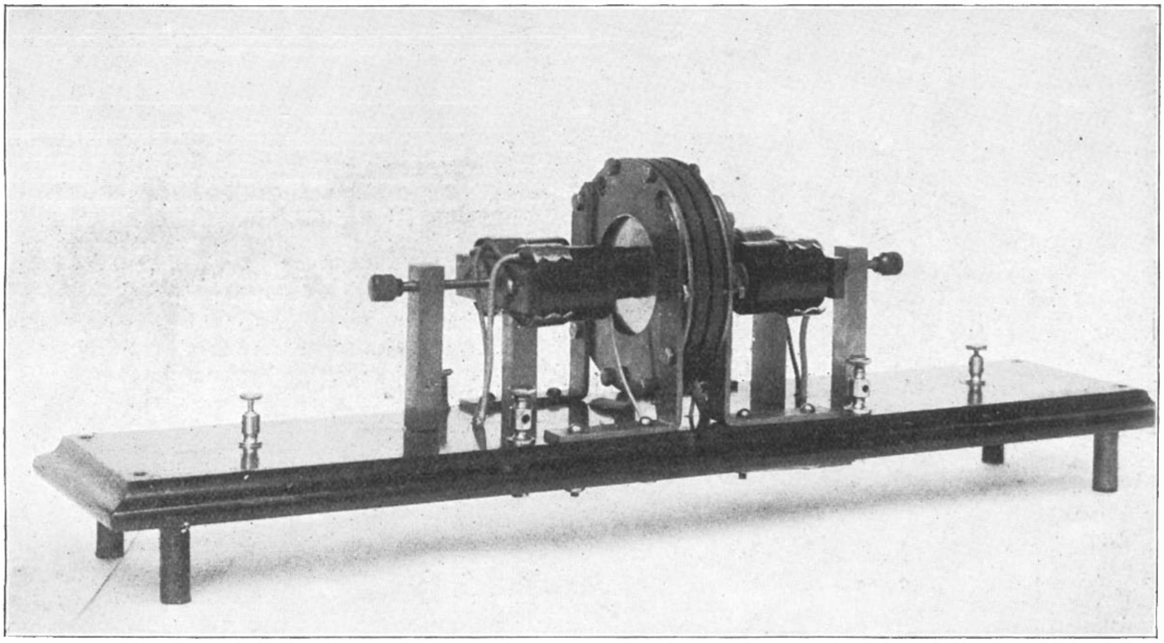


FIG. 3.—Dubilier water-cooled large current microphone.

The subject of wireless telephony is, therefore, one which holds out much promise for future achievement, and it is not surprising that it is attracting the attention of some of the leading workers in radiotelegraphy. J. A. FLEMING.

A BIRD WITH A HISTORY.[1]

A WELL-KNOWN ornithologist here gives us the fruits of many years of careful study devoted to a single species. His study has been diverse: at times it has lain among etymological dictionaries and curious old works on natural history, at times among the publications of

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[1] "The Gannet: A Bird with a History." By J. H. Gurney. Pp. li+567+plates. (London: Witherby and Co., 1913.) Price 27s. 6d. net.